Software Acquisition Life Cycle Measure Plan based on the revised "IEEE P1633\AIAA R-013A Recommended Practice on Software Reliability"

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Background (1)

- Report on the revision of *Recommended Practice, AIAA/ANSI, R-013-1992, Software Reliability* [1]. The revision has the joint sponsorship of the IEEE and the AIAA.
- Emphasis in the original document was on software reliability models, test phase data collection necessary to support the models, and model predictions of software reliability made in the test phase for non-networked software.
- In the ten years since the document was published, there have been notable developments in predicting reliability much earlier than the test phase – as early as the requirements phase [2, 3].

Background (2)

- Therefore, the revision will address reliability prediction over all phases of the software life cycle, since identifying errors early reduces the cost of error correction. In addition, there have been advances in modeling and predicting the reliability of networks and distributed systems
- These developments will be included in the revision.
  - The revision will be an important lifecycle software reliability process document to achieve the following objectives:
  - Provide high reliability in DoD and aerospace safety and mission critical systems.
- Provide a rational basis for specifying software reliability requirements in DoD acquisitions.
  - Improve the management of reliability risk.

Problem Definition (1)

- While software design and code metrics have enjoyed some success as predictors of software quality, the measurement field is stuck at this level of achievement.
- If measurement is to advance to a higher level, we must shift our attention to the front-end of the development process, because it is during requirements analysis that errors are inserted into the process.

Problem Definition (2)

- A requirements change may induce ambiguity and uncertainty in the development process that cause errors in implementing the changes.
- Subsequently, these errors propagate through later phases of development and maintenance.
- These errors may result in significant risks associated with implementing the requirements.
- For example, reliability risk (i.e., risk of faults and failures induced by changes in requirements) may be incurred by deficiencies in the process (e.g., lack of precision in requirements).

Potential Solution

- Identify the attributes of requirements that cause the software to be unreliable.
- Quantify the relationship between requirements risk and reliability.
- If these attributes can be identified, then policies can be recommended to DoD and NASA for recognizing these risks and avoiding or mitigating them during development.

Analysis of Results (1)

- Identified thresholds of risk factors:
  - Attributes of a requirements change that can induce reliability risk for predicting when the number of failures would become excessive (i.e., rise rapidly with the risk factor) [4].
- Two of the most important requirements risk factors of the Space Shuttle, as measured by their negative affect on software reliability, are *space* and *issues*.
- *Space*: amount of memory space required to implement the requirement change
- *Issues*: number of possible conflicts among requirements.

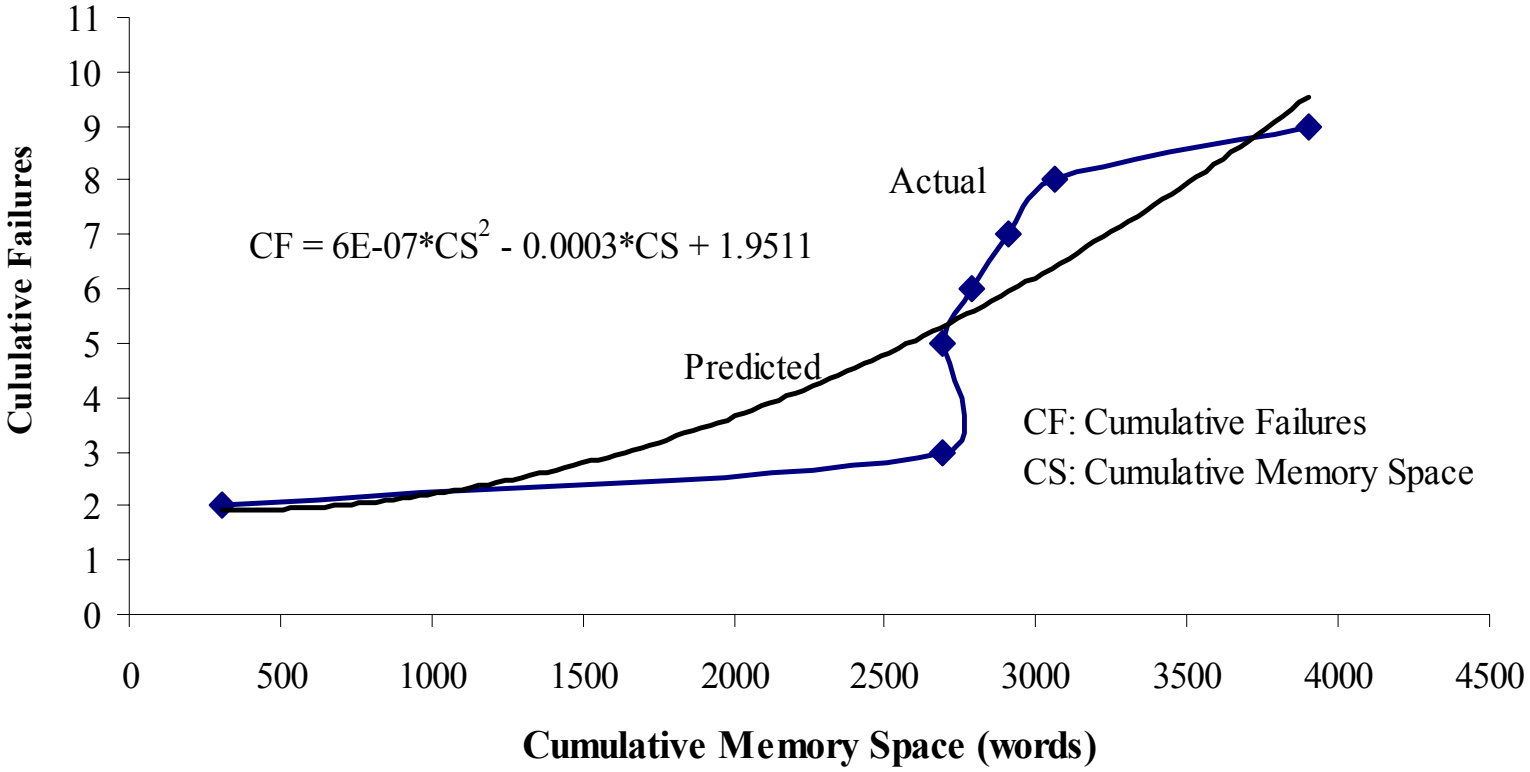
Analysis of Results (2)

- In [4], it was determined that *space* and *issues* had the highest statistically significant relationship with reliability.
  - The greater the cumulative memory space required to implement changes and the greater the number of cumulative conflicting requirements issues caused by the changes, the greater the negative effect on reliability.

Analysis of Results (3)

- An example is shown in Figure 1, where cumulative failures are plotted against cumulative memory space for both actual and predicted data.
  - The figure shows that when memory space reaches 2688 words, actual cumulative failures reach three and climb rapidly thereafter.

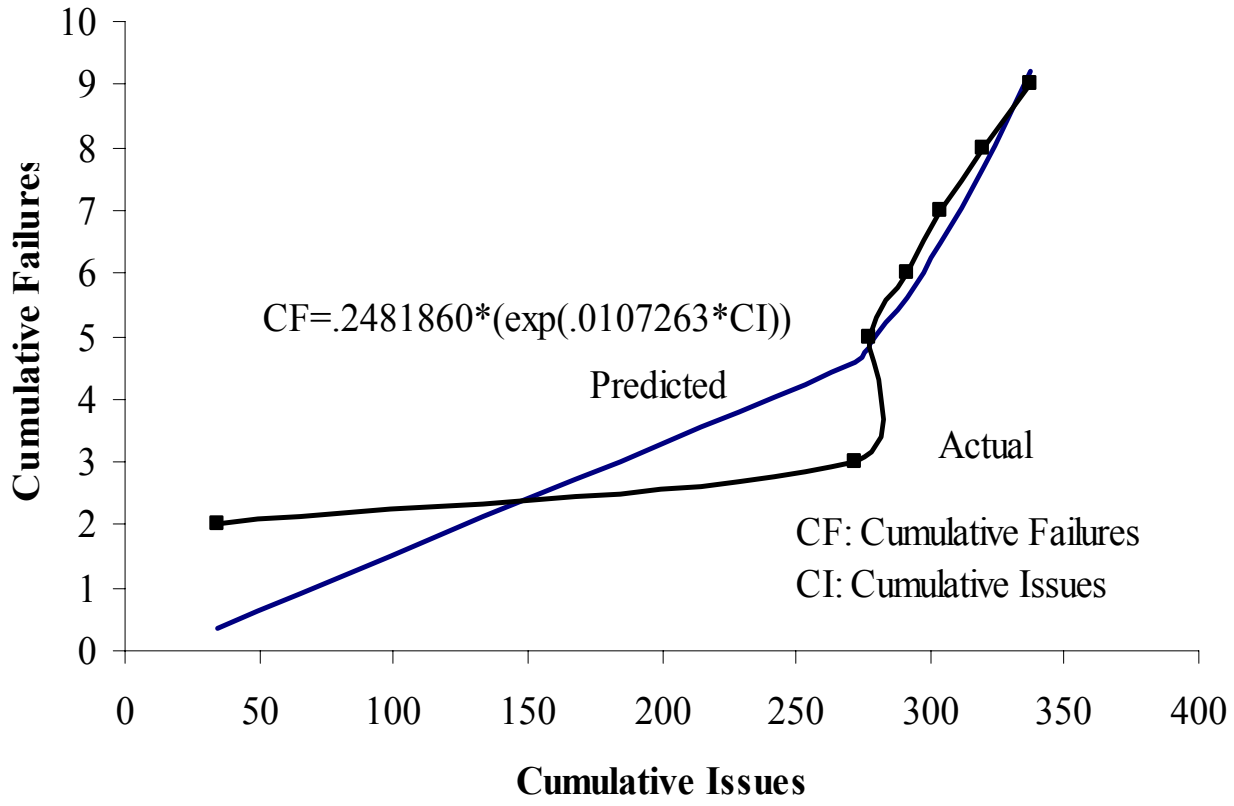
Figure 1: Failures vs. Memory Space



Analysis of Results (4)

- In Figure 2, cumulative failures are plotted against cumulative requirements issues, for both actual and predicted cases. When *issues* reach 272, actual cumulative failures reach three and climb rapidly thereafter.
- In both cases, a cumulative failure count of three has been identified as a *critical* value.

Figure 2: Failures vs. Issues



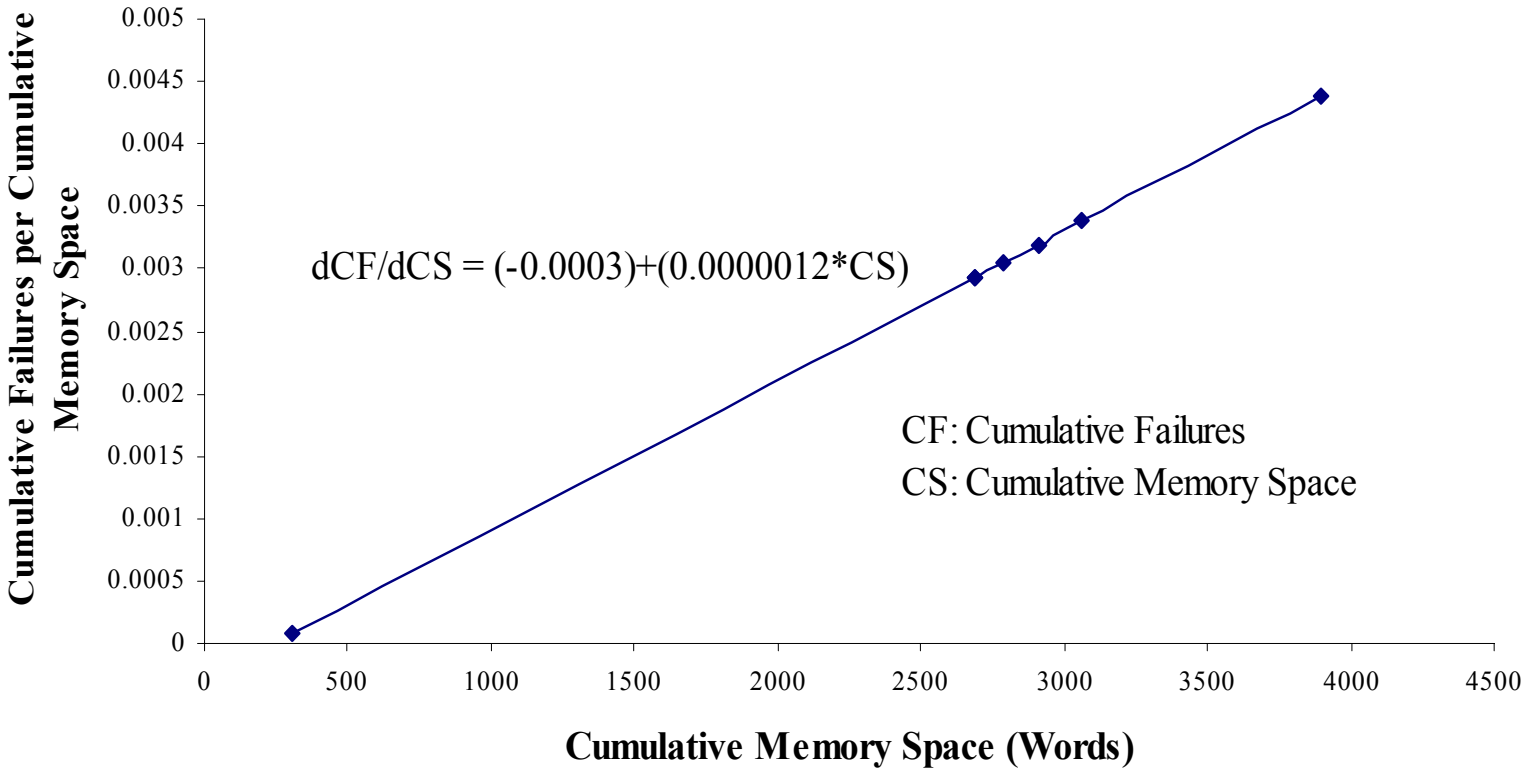
Analysis of Results (5)

- Although the counts of 2688 words and 272 issues provide estimates of the threshold to use in controlling the reliability of the next version of the software, the next version may not exhibit bends in the curves at the same value of risk factor.
- Therefore, the prediction equations and plots generalize the relationship between risk factors and reliability, such that they can be used to predict cumulative failures for *any* given value of cumulative risk factor.
- This process would be repeated across versions with the prediction equations being updated as more data is gathered.

Analysis of Results (6)

- Additional insight about the relationship between risk factors and reliability can be gained from the first derivative of the prediction equations in Figures 1 and 2 (i.e., rate of change). These are shown in Figures 3 and 4 for *space* and *issues*, respectively.
- Because the equation in Figure 1 is a second-degree polynomial, its derivative in Figure 3 is linear;
  - Thus, the prediction is a constant rate of change.

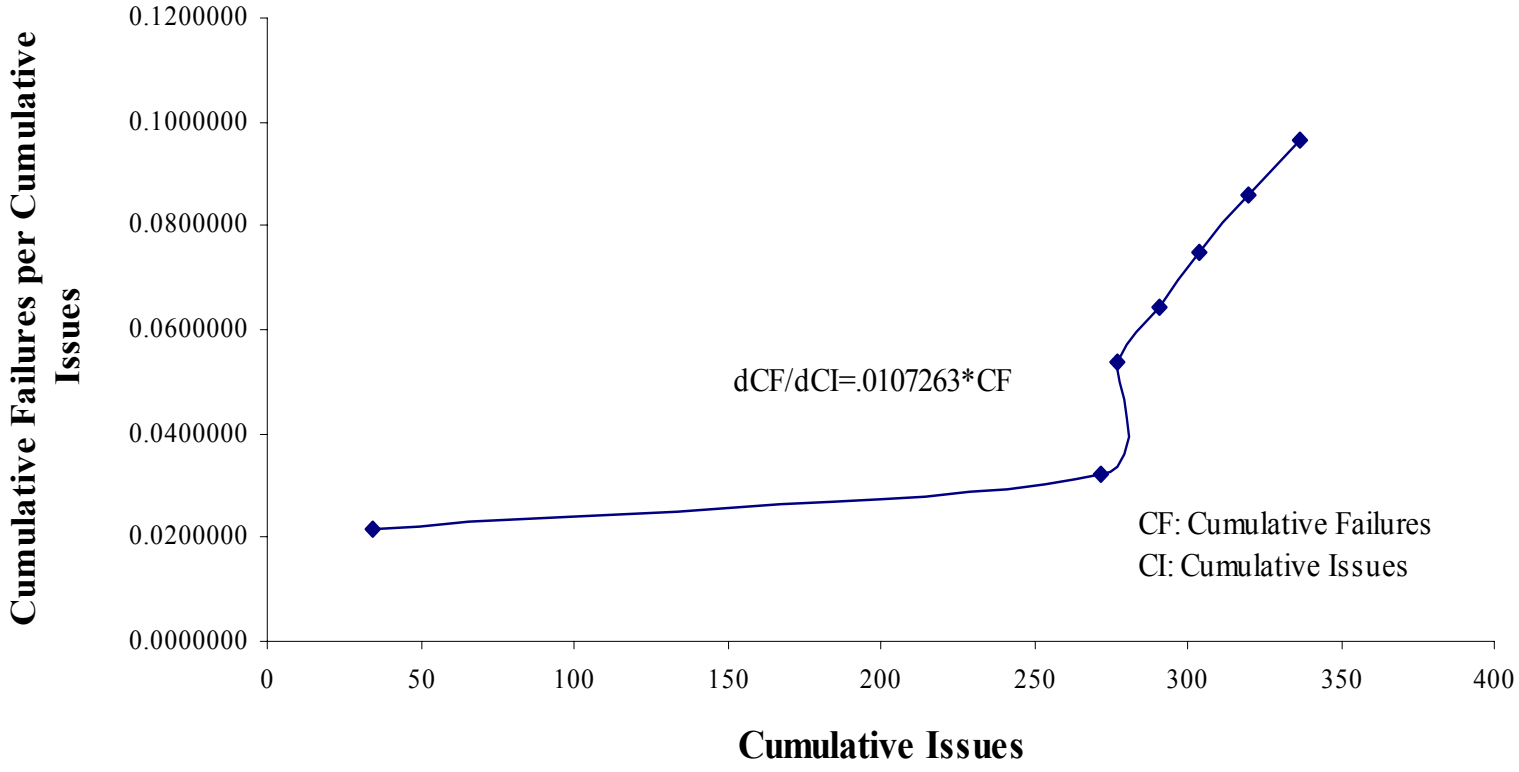
Figure 3. Rate of Change of Failures with Memory Space



Analysis of Results (7)

- In contrast, because the equation in Figure 2 is an exponential, its derivative is also an exponential and is simply the original function multiplied by a constant. This plot is shown in Figure 4.
- In comparing Figures 3 and 4, the implication is that we should have more concern about the negative effect on reliability of *issues* because of its predicted explosive growth rate.

Figure 4. Rate of Change of Failures with Issues



Analysis of Results (8)

- For the next version of this software, we want to predict the cumulative values of risk factors that correspond to given values of cumulative failures, particularly critical values.
- Figures 5 and 6, show the plots corresponding to the equations on the figures. These equations and plots were obtained by solving the equations of Figures 1 and 2 for cumulative risk factor as a function of cumulative failures. For example, if cumulative failures equal to 3 are considered critical, this would correspond to 1596 words of memory (Figure 5) and an issue count of 232 (Figure 6).

Figure 5. Memory Space vs. Failures

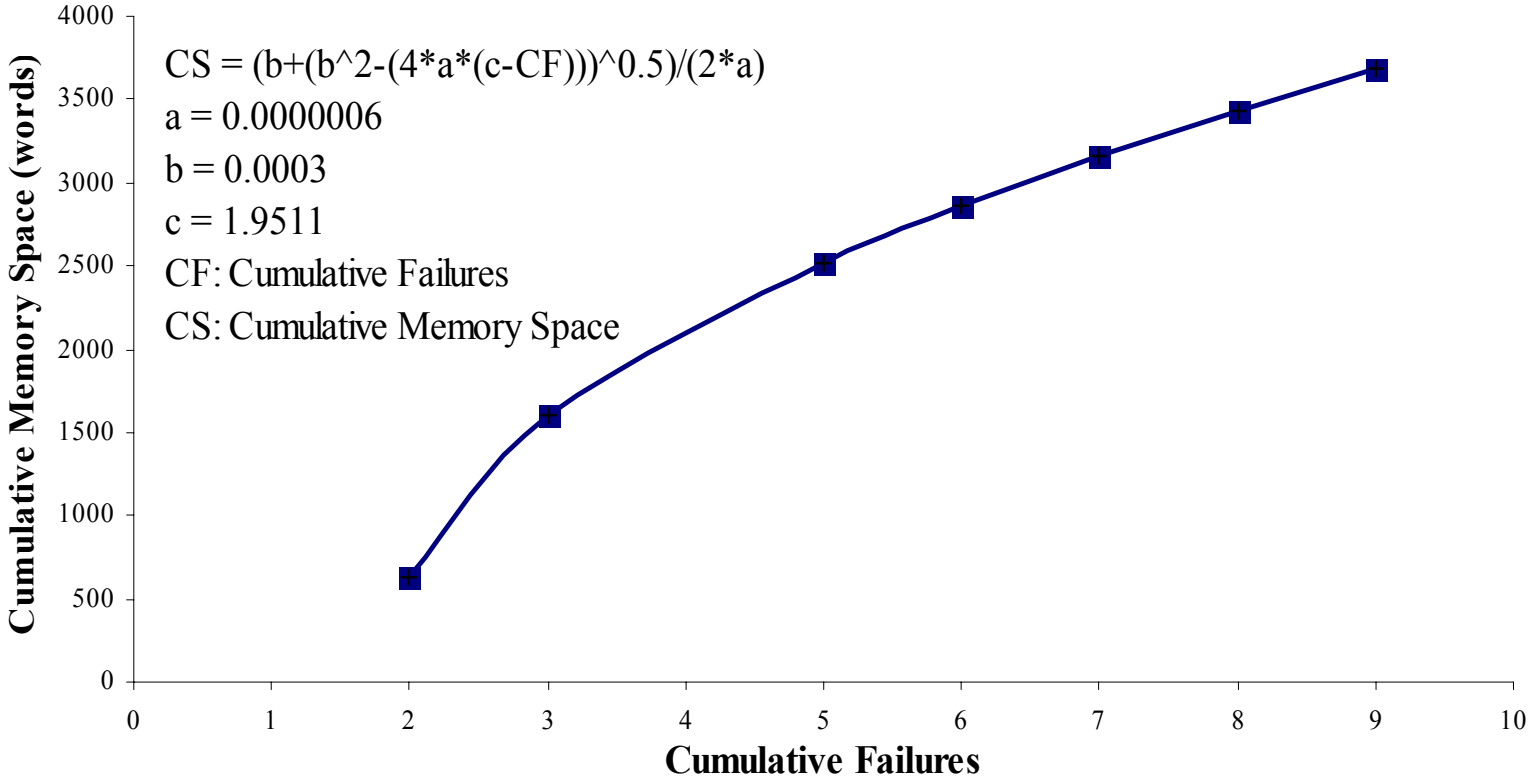
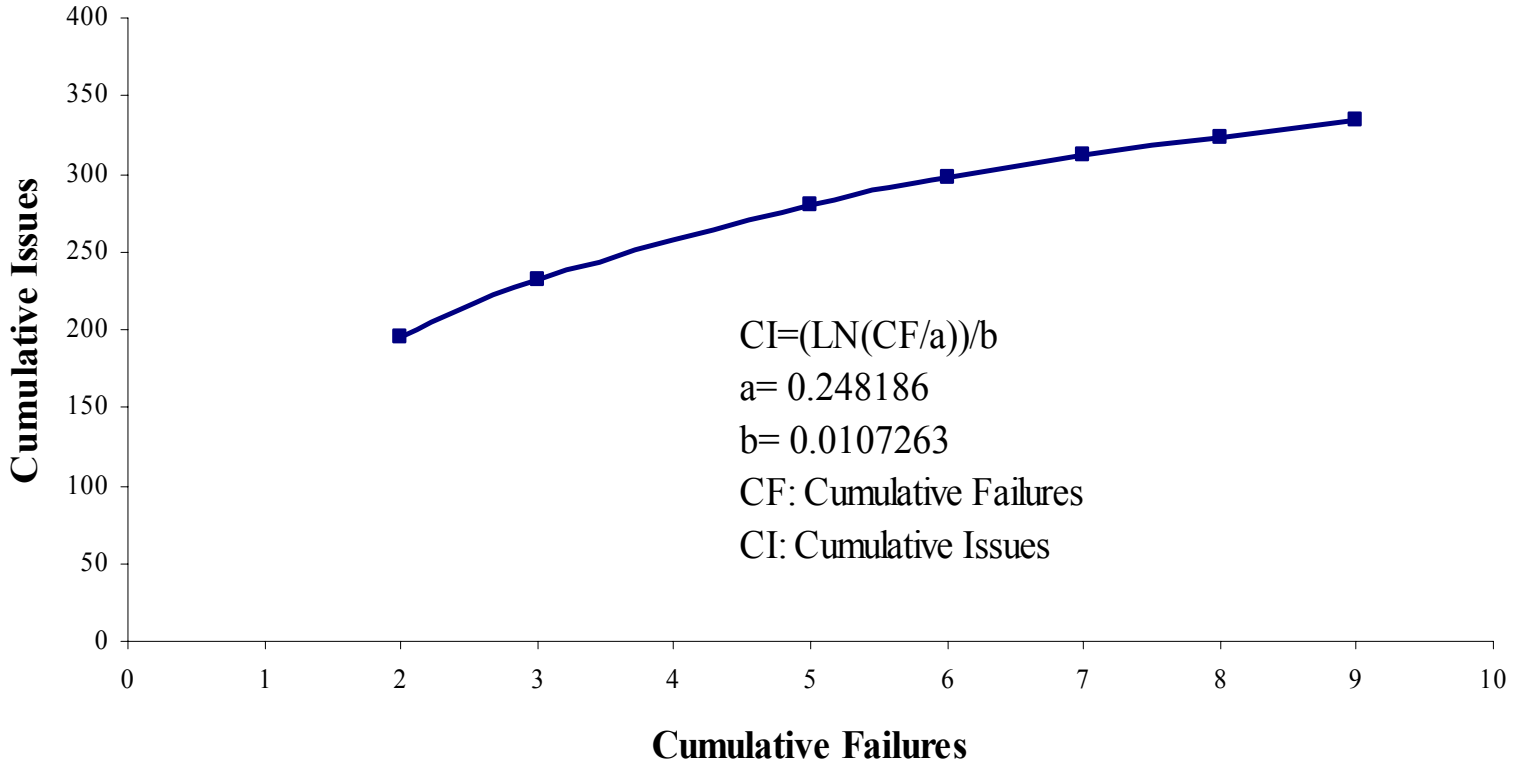


Figure 6. Issues versus Failures

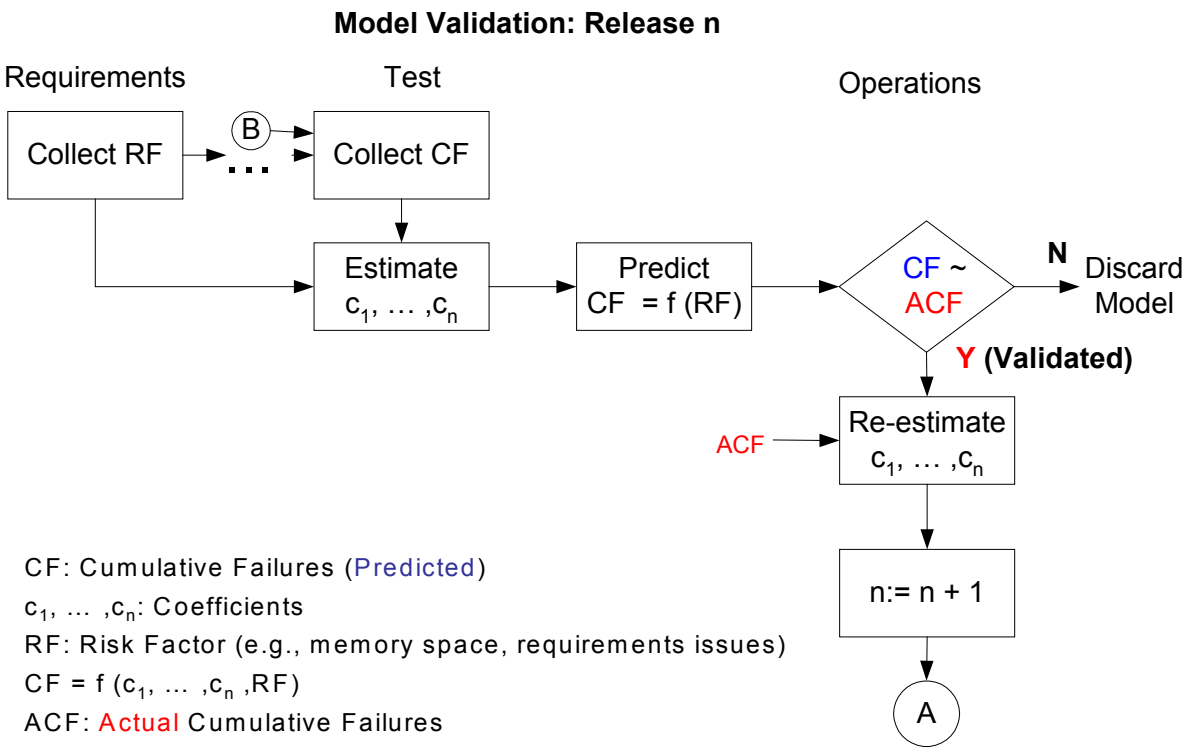


Reliability Risk Model Validation (1)

Release n

- Collect requirements *Risk Factor (RF)* data during *requirements* phase.
- - Collect *Cumulative Failure* (CF) data during *test* phase.
- - Use data to estimate coefficients of reliability risk prediction model.
- - Predict *CF* as a function of *RF* (e.g. size, complexity) during operations phase.
- Validate model against Actual Cumulative Failures (*ACF)* data.
- Re-estimate model coefficients using actual cumulative failure data.
- This approach has been demonstrated on the Space Shuttle avionics software [2, 3].

Reliability Risk Model Validation (2)

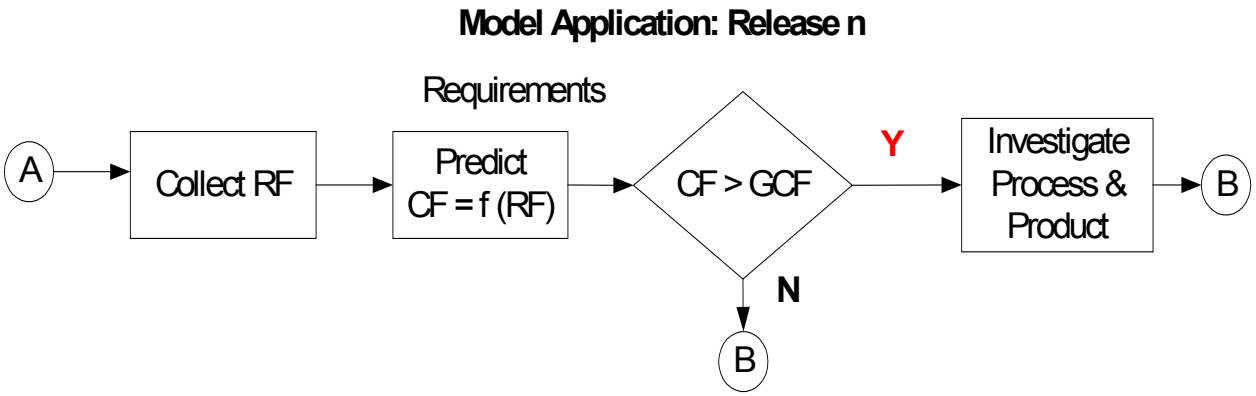


- CF: Cumulative Failures (Predicted)
- $c_1, \ldots, c_n$: Coefficients
- RF: Risk Factor (e.g., memory space, requirements issues)
- CF = f ($c_1, \ldots, c_n$, RF)
- ACF: Actual Cumulative Failures

Reliability Risk Model Application (1)
Release n+1

- Collect requirements *Risk Factor (RF)* data during *requirements* phase.
- Predict reliability *CF* as a function of *RF* during *requirements* phase.
- Determine whether Actual Cumulative Failures (*ACF*) *greater* than Goal Cumulative Failures (*GCF*) during *requirements* phase.
  - If this is the case, Investigate *Process* and *Product* for *possible* corrective action.
- Collect *Cumulative Failure* (CF) data during *test* phase.

Reliability Risk Model Application (2)



- CF: Cumulative Failures (Predicted)
- $c_1, \ldots, c_n$: Coefficients
- RF: Risk Factor (e.g., memory space, requirements issues)
- CF = f ($c_1, \ldots, c_n$, RF)
- ACF: Actual Cumulative Failures

  GCF: Goal CF

Summary

- *IEEE P1633 \ AIAA R-013A Recommended Practice for Software Reliability* will be revised for complete life cycle Software reliability Engineering process to achieve the following:
  - Provide high reliability in DoD and aerospace safety and mission critical systems.
- Provide a rational basis for specifying software reliability requirements in DoD acquisitions.
  - Improve the management of reliability risk.

References

- [1] AIAA/ANSI, Recommended Practice Software Reliability, R-013-1992, American Institute of Aeronautics and Astronautics (AIAA), 1801 Alexander Bell Drive, Reston, VA 20191-4344
- [2] Norman F. Schneidewind; “Requirements Risk versus Reliability”, Supplementary Proceedings of The 13th International Symposium on Software Reliability Engineering, Annapolis, Maryland, 12-15 November, 2002, pp. 41-45.
- [3] Norman F. Schneidewind, “Report on Results of Discriminant Analysis Experiment”, 27th Annual NASA/IEEE Software Engineering Workshop, 27th Annual NASA/IEEE Software Engineering Workshop, Greenbelt, Maryland, 5 December 2002.
- [4] Norman F. Schneidewind, "Investigation of the Risk to Software Reliability and Maintainability of Requirements Changes", Proceedings of the International Conference on Software Maintenance, Florence, Italy, 7-9 November 2001, pp. 127-136.